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Vulnerability Status of Rural Households to Climate Change and Extreme Events: A Comparative Study from three Agro-climatic Zones in Janamora District of Ethiopia.

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ABSTRACT

Rural communities, who are dominantly dependent upon natural resources, have always been adjusting their livelihood against the vagaries of climate. With the global climate change, these communities have been placed in greater vulnerability as the weather and extreme events have become more unpredictable. In order to formulate suitable policy measures to address their livelihood, assessment of local level vulnerability is very important. This paper analyzes the micro-level vulnerability of rural community in the three agro-climatic zones of Janamora district utilizing the data collected from 352 households from the three agro-climatic zones. The analysis is based on indices constructed from carefully selected indicators for exposure, sensitivity, and adaptive capacity. The indicators are weighted using Principal Component Analysis. The study elucidated high to low moderate vulnerability status of farming households of lowland community. The computed LVI of Kolla agro-ecology/Lowland, Woinadega agro-ecology/Midland and Dega agro-ecology/Highland are 0.696, 0.567, and 0.638. Furthermore, results suggest that the Kolla/lowland agro-ecology is more vulnerable in terms of natural assets (0.991) followed by climate variability (0.914). Policy measures and development efforts should be focused towards improving the adaptive capacity of the rural households, while keeping the post-disaster emergency relief measures in place for localities with higher exposure to climate extremes. The poorest households should be the primary target of any interventions.

Keywords: Exposure, sensitivity, adaptive capacity, livelihood assets

Background of the Study

There is a general consensus that the Earth's climate is undergoing changes, and observations are consistent with scientific expectations regarding the increasing concentrations of greenhouse gases in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) in 2007 reported that there is a statistically significant increase in the global mean state of the climate or in its variance, and further increases are expected if carbon dioxide and greenhouse gas emissions are not controlled. Human activities, such as burning of fossil fuels and deforestation, have altered the global climate, resulting in increased temperature and alter the amount, intensity and distribution of precipitation and sea level rising.

Ethiopia's agricultural sector is the mainstay of the country's economy. It constitutes more than half of the nation's gross domestic product (GDP), generates more than 85 percent of the foreign exchange earnings, and employs about 80 percent of the population. Ethiopia's dependence on agriculture makes the country more vulnerable to the adverse impacts of climate change on crop and livestock production (Deressa et al., 2009).

Ethiopia is vulnerable to climate variability and change because large segments of its population are poor, dependent on income opportunities that are highly sensitive to the weather, and have low access to education, information, technology, and health services. They have low adaptive capacity to deal with the consequences of climate variability and change. It is one of the poorest countries in the world, where 77.5 percent of the people live on less than two dollars a day, 46 percent of the total population is undernourished and 85 percent of the population depends on agriculture to make a living (Deressa et al.,2009).

Vulnerability, its three components (exposure, sensitivity, adaptive capacity) as well as their determinants are specific to place and system and they can vary over time by type and by climatic stimuli (Adger et al., 2007). Thus, vulnerability is context-specific, and the factors that make a system vulnerable to the effects of climate change depend on the nature of the system and the type of effect in question (Brooks, Adger and Kelly, 2005), i.e. the factors that make farmers in semi-arid Ethiopia vulnerable to drought will usually not be identical to those that make farmers in other parts of Africa vulnerable to extreme weather events.

Several studies had been conducted to assess vulnerability of community to climate change impacts using different approaches in Ethiopia. These approaches always defer community to community and region to region, depending up on each system, as IPCC (Fourth Assessment Report, 2007) has defined vulnerability primarily in terms of system. This study has developed a peculiar approach to assess vulnerability of a mountain community, depending up on its own system. The need of vulnerability assessment in grassroots level has become very essential. Large numbers of adaptation programs have turned failed simply because they were not able to properly identify the major aspects and magnitude of vulnerability of the community where projects were to be launched. Therefore, this research tends to adopt wide, pragmatic and largely community based approach to assess vulnerability of community which is prone to the impacts of climate change in different agro-climatic zones of Janamora district.

Research Methods

A total of 352 pastoralist households were selected for interviews a using semi-structured questionnaire to elicit responses between February and July 2016. Systematic purposive sampling was used to select drought-prone divisions in the Ethiopia which include Janamora district. Households were selected based on accessibility of the area. Consequently, 3 locations were selected from which the sample households were selected randomly proportional to population size. A semi-structured questionnaire was used to interview the household heads. The questionnaire was divided into the following: demographic and economic household characteristics, livestock and crops production, access to extension services, credit access, hazards occurrence, perception level, and adaptation strategies pursued, different coping strategies, level of resilience and other relevant information. In addition, rainfall and temperature datasets relevant for this study were obtained from Meteorological Services Agency of Ethiopia. The SPSS software was used to analyze the socio-economic data obtained. The data was entered into Epi-Data software for data quality control before exported into SPSS software for analysis. Plus, XLstat was used to analyze the meteorological data.

In this study, three different composite indices were applied for analyzing vulnerability to climate change. These three indices are: LVI, LVI-IPCC, and LEI. They are all climate change-focused and they are based on the same principles. The methodology used by Hahn et al. (2009) in their study for assessing the risks derived from climate variability and change in Mozambique, have been adapted to develop both the LVI and LVI-IPCC indices. Nevertheless, and as the authors suggest, modifications have been made to adapt it to the context of specific case study.

The LVI provides information of which components determine vulnerability. The LVI-IPCC indicates which of the three factors (exposure, adaptive capacity and sensitivity) influence the most when determining the vulnerability and the LEI indicates which types of capital assets affect a household more severely.

Table 1.Methodology used to calculate the indices.

Index	*Major components*	*Standardized sub-components formula*	*Major components formula*	*Overall index formula*	*Index value*
LVI	7 livelihood components	$Index = \frac{\text{Obser}-\text{Min}}{\text{Max}-\text{Min}}$	$Md = \frac{\sum_{i=1}^{n} \text{Index}}{n}$	$\text{LVI} = \frac{\sum_{i=1}^{7} \text{WMi Mdi}}{\sum_{i=1}^{7} \text{WMi}}$	0=least vulnerable to 1=most vulnerable
LVI-IPCC	Adaptive capacity, exposure and sensitivity	$Index = \frac{\text{Obser}-\text{Min}}{\text{Max}-\text{Min}}$	$\text{CF} = \frac{\sum_{i=1}^{n} \text{WMi Mdi}}{\sum_{i=1}^{n} \text{WMi}}$	$LVI - IPCCr = (er - ar) * Sr$	-1=least vulnerable to 1=most vulnerable
LEI	5 household Capitals	$Index = \frac{\text{Obser}-\text{Min}}{\text{Max}-\text{Min}}$	$CV = \frac{\sum_{i=1}^{n} \text{Li}}{n}$	$\text{LEI} = \frac{\sum_{i=1}^{5} \text{Wi Cvi}}{\sum_{i=1}^{5} \text{Wi}}$	0=least affected to 1=most affected

Result and Discussion

Among the three hundred and fifty five respondents, the average age of respondents was approximately 48 years, with an experience in farming of about 27 years. Most respondents were men, and only 13% of the respondents were women.

Table 2. Summary of the LVI results for 7 capitals of the three agro-ecologies of Janamora district

Major Components	*Kolla* agro-ecology/ Lowland	*Woinadega* agro-ecology/ Midland	*Dega* agro-ecology/ Highland
Human Capital	0.765	0.691	0.5444
Natural Capital	0.991	0.721	0.712
Financial Capital	0.601	0.645	0.621
Physical Capital	0.713	0.346	0.615
Social Capital	0.322	0.452	0.631
Institutions	0.567	0.511	0.629
Climate Variability	0.914	0.602	0.714
LVI	**0.696**	**0.567**	**0.638**

The computed LVI of *Kolla* agro-ecology/Lowland, *Woinadega* agro-ecology/Midland and *Dega* agro-ecology/Highland are 0.696, 0.567, and 0.638 respectively.

Empirically, the vulnerability indices of the major components ranged from 0.322 to 0.991 as shown in table 2 above. The Indices being relative values are compared across three different agro-ecological zones (ACZ) in Janamora district of North West Ethiopia within the study sample only. For instance, the Vulnerability Index for the Natural capital consists of water, land, and forest resource aspects. According to the result, this component of the LVI shows lowland agro-ecology of Janamora district to be the most (0.991) vulnerable, and Highland to be the least (0.712) vulnerable. Almost all (88.65%) the households interviewed in *Kolla*/lowland agro-ecology reported they don't have access to irrigation compared to households in *Dega*/highland (64.22%) and midland agro-ecology (49.38.2%) regions. Water is usually sourced by women and young girls hence distant water sources increases the time burden of household chores and affects time for care in the case of women, and school attendance in the case of the girl child. *Kolla*/lowland agro-ecology reported the highest percentage (81.2%) of households that do not have a consistent water supply.

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The second major sub-component is Human capital which consists of 13 sub components. In terms of socio-demographic profile, *Kolla*/lowland agro-ecology (0.765) was found to be the most vulnerable followed by the *Woina-Dega*/midland agro-ecology (0.691). Majority of the household heads in *Kolla*/lowland agro-ecology (56.4%) reported not having any formal education. Formal education tends to improve the ability of smallholder farmers to better comprehend issues affecting them and therefore look for possible solutions at the appropriate places. Inability to read and write limits smallholder farmer's access to information especially from written sources increases their susceptibility to climatic stresses.

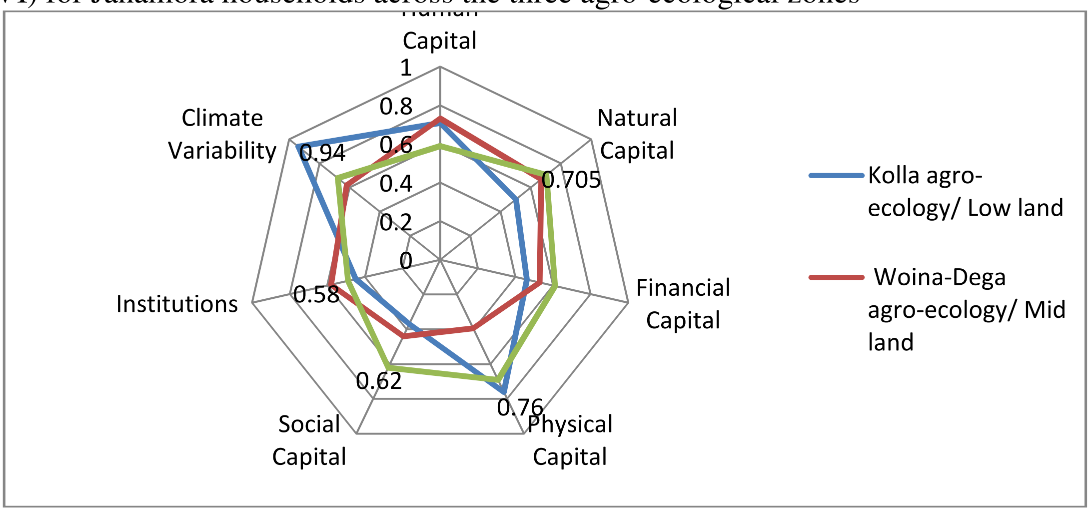
Social capitals are the third major component which is made up of three sub components. When results of all the sub components are aggregated, *Dega*/highland agro-ecology is most vulnerable indexed 0.631. For instance percentage of households who have loose ties with neighbors/relatives are about 52.4% in this agro-ecology followed by *Woina-Dega*/midland agro-ecology which is 42.8%.

Physical capitals are the fourth major component which is made up of four sub components. When results of all the sub components are aggregated, *Kolla*/lowland agro-ecology is found to be the most vulnerable (0.713) in terms of livestock holding and infrastructure.

The fifth major component of financial capital is also made up of four sub components. Even though the indices for the three agro-ecologies are nearly the same, *Woina-Dega*/midland agro-ecology is found to be the most vulnerable (0.645) in terms of income and access to credit services. Households in this agro-ecology reported receiving more money than giving help to others when compared to households in the other kebeles.

The sixth major component is climate variability component which is comprised of six sub components as shown in table above. *Kolla*/lowland agro-ecology was found to be the most vulnerable, in terms of natural disasters and climate variability. Majority of farmers in all three regions did not receive early warning about impending natural disaster such as floods or droughts.
The last major component is Institutional capital consisting of three variables. *Dega*/highland agro-ecology is most vulnerable to institutional capitals indexed 0.629.

Figure 1: Vulnerability Spider Diagram of the Major Components of the Livelihood Vulnerability Index (LVI) for Janamora households across the three agro-ecological zones

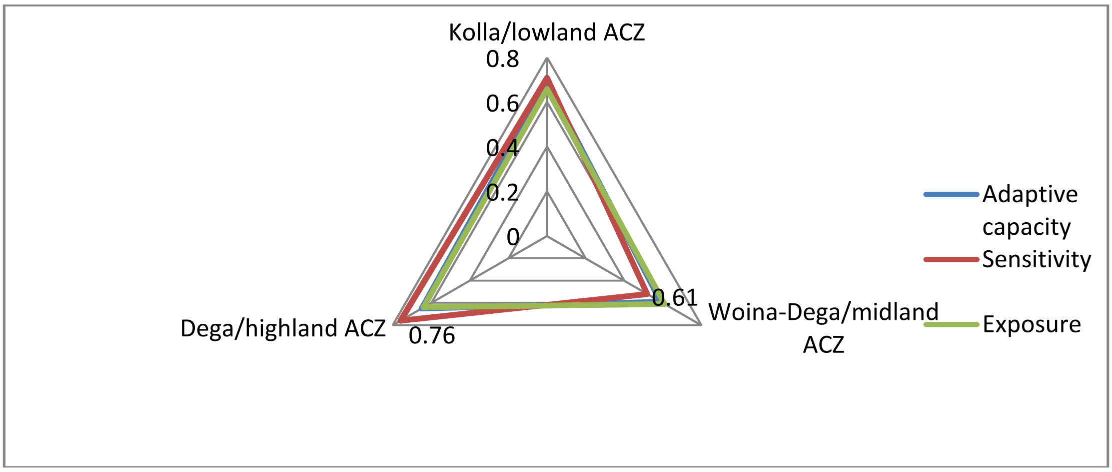


Source: Computation from field survey 2016

Vulnerability Status of households in the high land of Janamora district of Ethiopia

As indicated from the table (5) below, in the highland parts of Janamora, access to information has the lowest value (0.32) among others which affects the adaptive capacity of farming households. Among the components that have a low weight on the vulnerability, we find knowledge and skills. Having Radio, Mobile, and Network at home, thus being connected to external information, is very important for example to consulting weather information, government decisions, events and can be helpful to perform their functions in agriculture. Also we can observe that most farmers exchange information between them, and that for the dynamics of a society is very useful.

Figure 2: Vulnerability Triangle Diagram of the Contributing Factors of the Livelihood Vulnerability Index-IPCC (LVI–IPCC) for the three agro-ecologies of Janamora district



The LVI IPCC estimates for *Kolla*/lowland, *Woina-Dega*/midland and *Dega*/highland are 0.104, 0.081 and 0.101 respectively. This implies that overall; vulnerability context particularly in terms of this study i.e. climate change, Kolla/lowland is the most vulnerable followed by Dega/highland agro-ecology.

Table 3. IPCC-LVI values in terms of the three major vulnerability indicators

	Kolla/lowland ACZ	*Woina-Dega*/midland ACZ	*Dega*/highland ACZ
Adaptive capacity	0.69	0.59	0.65
Sensitivity	0.71	0.52	0.76
Exposure	0.66	0.61	0.64

The overall value for the LV-IPPC expresses the moderate vulnerability to climate changes and climate variability. The value 0 indicates that the community is more exposed to climate extremes and natural disasters than its capacity to adapt or overcome these adverse situations. As we can see, the diagram is clearly shifted towards exposure. Thus sensitivity, with a value 0.76, is the factor that contributes most to the vulnerability of the Dega/highland community.

Adaptive capacity of households across the three agro-ecologies of Janamora district

Table 4. Percentage of rural farming households by levels of adaptive capacity

Level of adaptive capacity	Agro-climatic zone in percentage			Average adaptive capacity
	Midland ACZ	Highland ACZ	Lowland ACZ	
Low	22	61	64	0.69
Moderate	27	27	22	0.59
High	51	12	14	0.65

The classification of scores in three adaptive capacity levels shows that majority of the respondents (64%) in lowland agro-climatic zone have low adaptive capacity, 22% have moderate adaptive capacity and only 14% have high adaptive capacity. In midland agro-climatic zone, majority of the respondents (51%) have high adaptive capacity, 27% have moderate adaptive capacity and only

22% have low adaptive capacity. With respect to the context in highland agro-climatic zone, majority of the respondents (61%) have low adaptive capacity, 27% have moderate adaptive capacity and only 12% have high adaptive capacity. The low adaptive capacity rating of most farming households in almost all the three ago-climatic zones is explained by their low scores in information and physical capital indicators of adaptive capacity.

Coefficient of determination between LVI (livelihood vulnerability index) and sub-components

Table 5 demonstrates the sub-components that were found to correlate strongly with the adaptive capacity score of rural farming households in Janamora district of Northwest Ethiopia. Therefore, these are the 9 drivers that best explain the adaptive capacity of rural farming community.

Table 5. Sub-components with strong correlation from the three agro-climatic zones (R^2 > 0.80)

R^2 value	*Sub-component*	*Major component*
0.924	Distance to the nearest Drinking Water Source	Physical capital
0.909	Households own asset that allows them to have up-to-date information (Mobile, Network, TV, Radio)	Information
0.892	Distance to the nearest Health Facility	Physical capital
0.871	HHs family member with off farm employment	Financial capital
0.863	Distance to the nearest Primary School	Physical capital
0.855	HHs with access to credit to any financial institutions	Financial capital
0.851	Access to Agricultural inputs	Technological capital
0.836	Households where head of households has attended school	Human capital
0.804	HHs who do not receive any kind of support/help from neighbours/relatives	Social capital

Correlations vary within and between sub-components. The type of component with the greatest number of highly correlated sub-components is the physical capital, where 62.4% of the subcomponents were found to have a strong correlation (R^2 > 0.80) with the adaptive capacity sores. The second type of major component with the largest number of subcomponents correlated to the adaptive capacity sore is the financial resources with 34.8%.

Non-Parametric Test Result

The next step was to determine whether there were statistically significant differences in household adaptive capacity once households were grouped based on various demographic characteristics. Non-parametric statistical tests were used, where household adaptive capacity was the test variable, and the demographic variables were used to group the households in a way that is relevant to each agro-climatic zones of Janamora district in North West Ethiopia. Post-hoc Mann-Whitney U pair-wise comparisons were performed to indicate the direction of the effect, where there was a statistically significant difference between groups.

Households were grouped based on the following characteristics: 1) ago-climatic locations of the households, 2) size of the household, 3) number of females in the household, 4) number of males in the household, 5) head of household's age.

The test results showed significant differences in household adaptive capacity between the three agro-climatic zones, Chi Square (352) = 112.12, p=0.000. Post-hoc Mann-Whitney U pair-wise comparison tests indicate statistically significant differences in adaptive capacity between households in highland agro-climatic zone, lowland agro-climatic zone, and midland agro-climatic zone. It was found that households midland agro-climatic zone having significantly higher adaptive capacity than households in highland and lowland agro-climatic zones.

The Kruskal-Wallis test was also conducted to evaluate whether the level of vulnerability of rural farm households differ as a function of the age of the head of household. Households with an 'adult' head of household (p=0.034) and with a 'senior' head of household (p=0.007) had significantly higher adaptive capacity scores than households with a 'young' head of household in all the three agro-climatic zones of Janamora district.

In terms of households size, the test result indicate that medium sized households (p=0.001) had significantly higher adaptive capacity scores than 'small' households. The findings further elucidated that there is also a significant difference in household adaptive capacity based on the number of males in the house and for number of females in the house (p=0.002).

Conclusions and Recommendations

The purpose of this study was to explore the extent and magnitude of vulnerability in the area. The vulnerability indices are all straightforward methods that use both empirical and theoretical insights to select and aggregate factors that affect vulnerability. The LVI, specifically, has the advantage of allowing household-level targeting, as opposed to targeting an entire community.

The main intention of applying the LVI and LVI-IPCC is to help identify vulnerable communities, to gain understanding of the factors that determine vulnerability, and to prioritize the potential areas for intervention. They should be used in the development research context, by development organizations, governments and policy-makers, in order to proceed to the application of corrective measures, and therefore aim to improve their adaptive capacity and increase their resilience to global and climate change.

It can be strongly believed that in order to suggest the best paths to reduce these communities' vulnerability, participative and deliberative processes should be held, where the relevant stakeholders from every village could be involved and are given a voice as to what would be the best ways to proceed. Additional recommendations for future studies are to include governance indicators, as civil and political rights and opportunities are very relevant for livelihood strategies and assessment. Also, including a more extensive global context could reveal important information for long term vulnerability and predictions.

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